U.S. Department of Energy
Energy Efficiency and Renewable Energy

biomass program

# Biomass Gas Cleanup Using a Therminator

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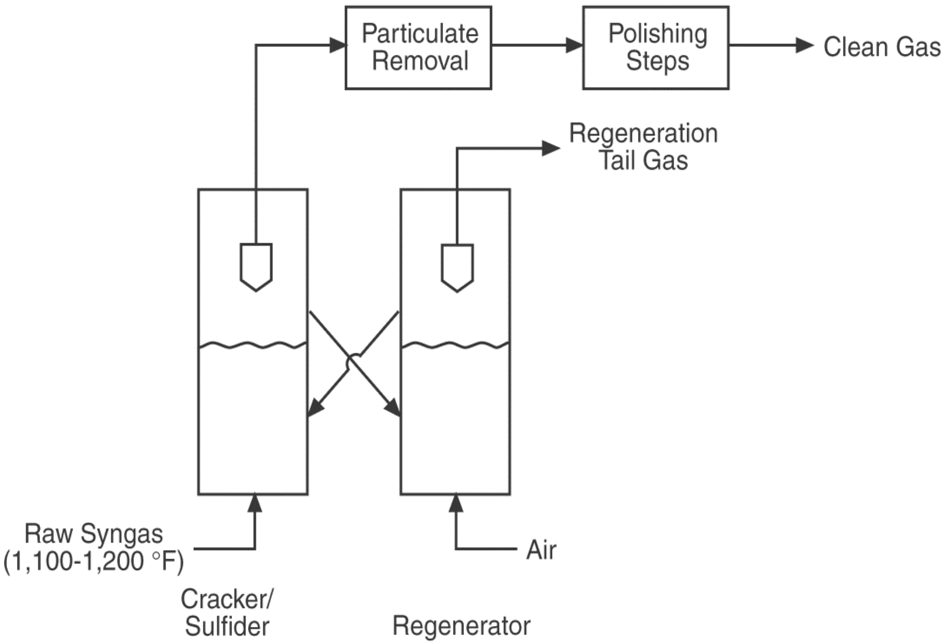
# Presentation Outline



- **Project Background**
- **Technical Feasibility and Risks**
- **Competitive Advantage**
- **Project Overview**
- **History and Accomplishments**
- **Plan/Schedule**
- **Critical Issues and Show-stoppers**
- **Plans and Resources for Next Stage**
- **Summary**

# Project Background

- Fluidized-bed gasification is a technology of choice for biomass utilization
  - flexibility with respect to fuel and desired end products
  - easy scale up (no known size limitations)
- Gas cleanup to remove particulates, tar, ammonia and hydrogen sulfide is critical to enable widespread deployment
- Project aims to develop a novel therminator process for cleanup of gas from a fluidized-bed biomass gasifier
  - coupled fluid-bed reactors
  - attrition resistant triple function catalyst system



# Pathways and Milestones – C-level and Project Milestones



| Ag Residues | Perennial Grasses<br>Woody Crops | Pulp and Paper | Forest Products |
|---|---|---|---|
| **Validate Cost-effective Gas Cleanup Performance** | | | |
| M 4.11.3<br>M 4.12.3 | M 5.11.3<br>M 5.12.3 | M.6.3.4 | M 7.1.4 |
| **Validate integrated gasification and gas cleanup at pilot scale** | | | |
| M 4.11.5<br>M 4.12.5 | M 5.11.5<br>M 5.12.5 | M.6.3.5 | M 7.1.5 |

| **Project Milestones** | Type | Performance Expectations | Due Date |
|---|---|---|---|
| Determine optimum catalyst combination | D | Remove tar to < 0.1 g/m$^3$, 90% of $NH_3$, and $H_2S$ to < 20 ppmv in a simulated laboratory reactor | 9/30/ 2006 |
| Demonstrate catalyst circulation in therminator | D-J | Circulate attrition-resistant catalyst for 24 hours without upsets | 9/30/ 2006 |
| Slip stream test of therminator system | D | Conduct a slip-stream test of up to 100-h duration using actual gas from Cratech's pilot-scale gasifier | 8/31/ 2007 |

# Technical Feasibility and Risks



- Technical Feasibility
  - gasification at 730°C
  - tar and ammonia removal at ~650°C
    - reforming
    - cracking
  - continuous catalyst regeneration/makeup
  - heat integration
- Risks
  - catalyst must be attrition resistant
  - catalyst needs to withstand reducing and oxidizing environments

# Competitive Advantage



- Significantly higher thermal efficiency than low-pressure combustion: >30% vs <20%
- Cleanup at elevated pressure reduces equipment volume/cost
- Cracking at moderate temperatures compared to Ni-based catalysts (~900°C)
  - reduces catalyst degradation
- Continuous catalyst regeneration ensures high contaminant removal efficiency

# Project Overview



Objective: Develop the therminator module for biomass gas cleanup at 600-700°C (1112-1292°F).

Goal:
tar < 0.1 g/m3
$NH_3$ > 90% decomposition
$H_2S$ < 20 ppm

Duration: 36 months

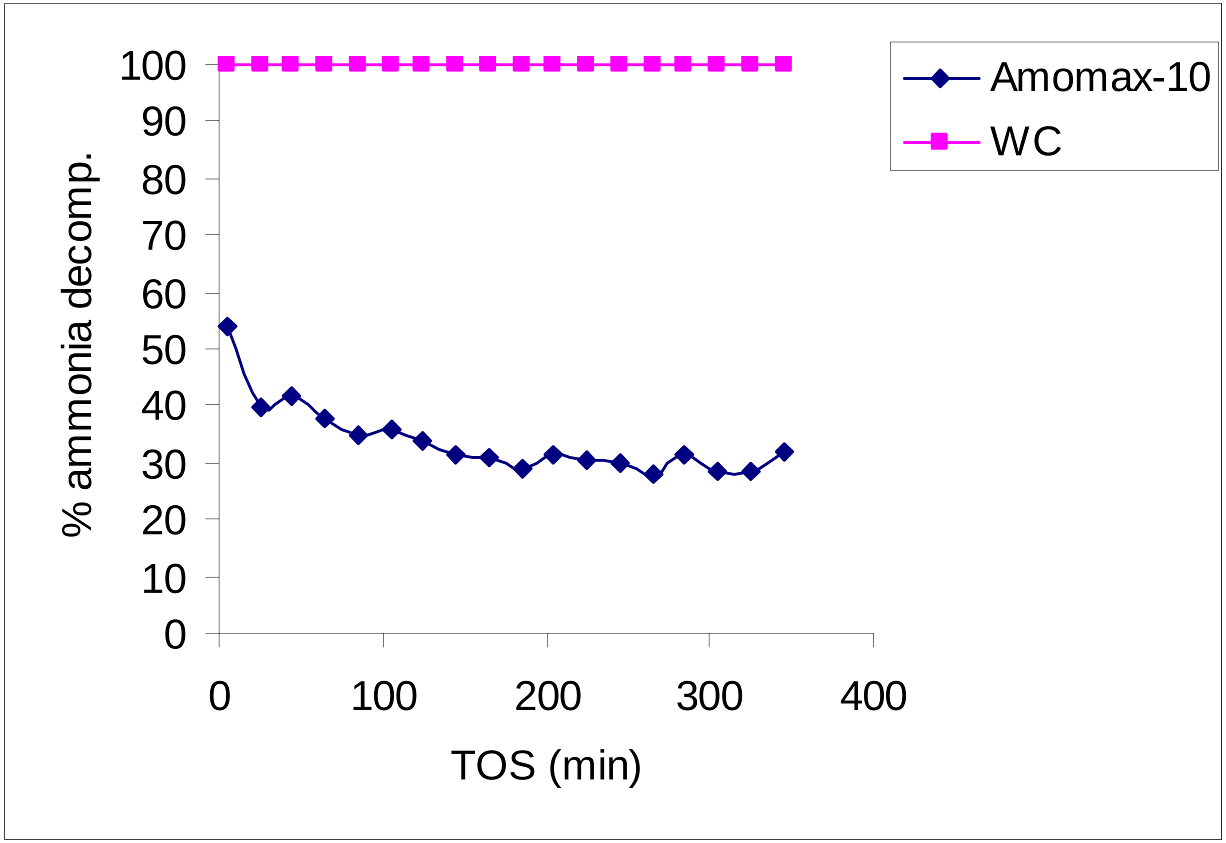
Tasks:
- Task 1 Laboratory testing and catalyst scale up
- Task 2 Bench-Scale therminator testing
- Task 3 Technology demonstration
- Task 4 Engineering Evaluation and Commercial Assessment

Team:
- RTI
- Clemson University
- Cratech
- Sud-Chemie

# Task 1
# Progress to Date

- Baseline catalysts have been selected and a few candidate catalysts have been prepared
- Micro reactor system for $NH_3$ decomposition study has been commissioned
- Micro reactor system for the cracking studies is nearing completion
- Candidate equilibrium FCC catalyst has been obtained in sufficient quantity
- Spray dryer has been commissioned for preparing FCC-type catalysts

# Ammonia decomposition as a function of TOS for Amomax-10 and WC catalysts at 650°C



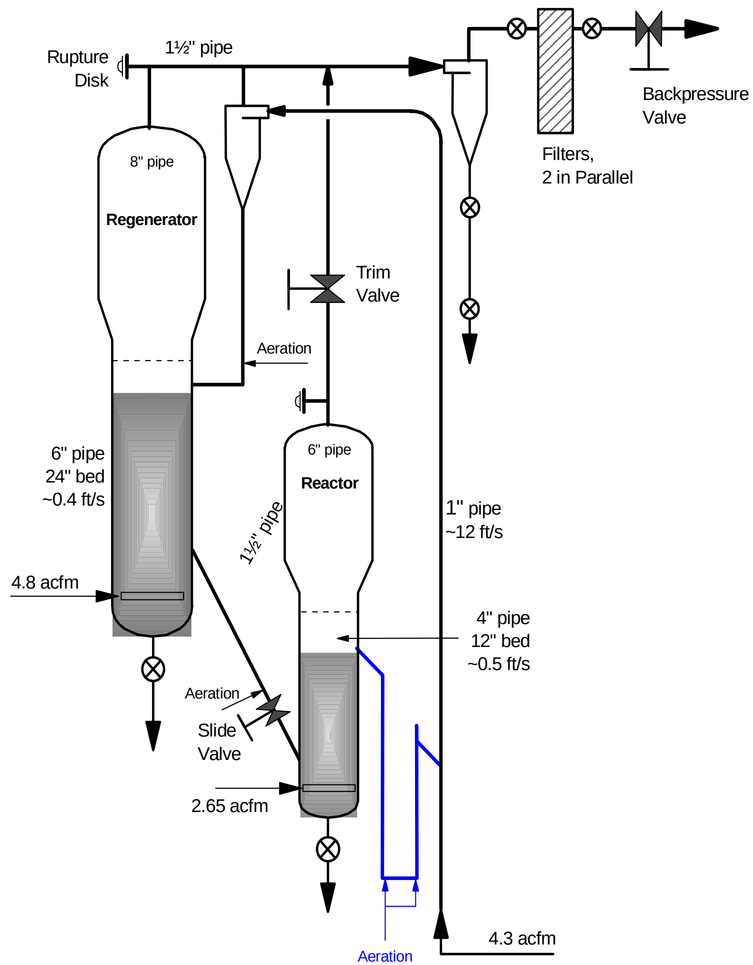
# Task 2
# Progress to Date

- Cold flow model of the therminator has been commissioned
- Data is being obtained to assist in the design of the hot therminator system
- Design of the hot therminator system is about 60% complete

# History and Accomplishments



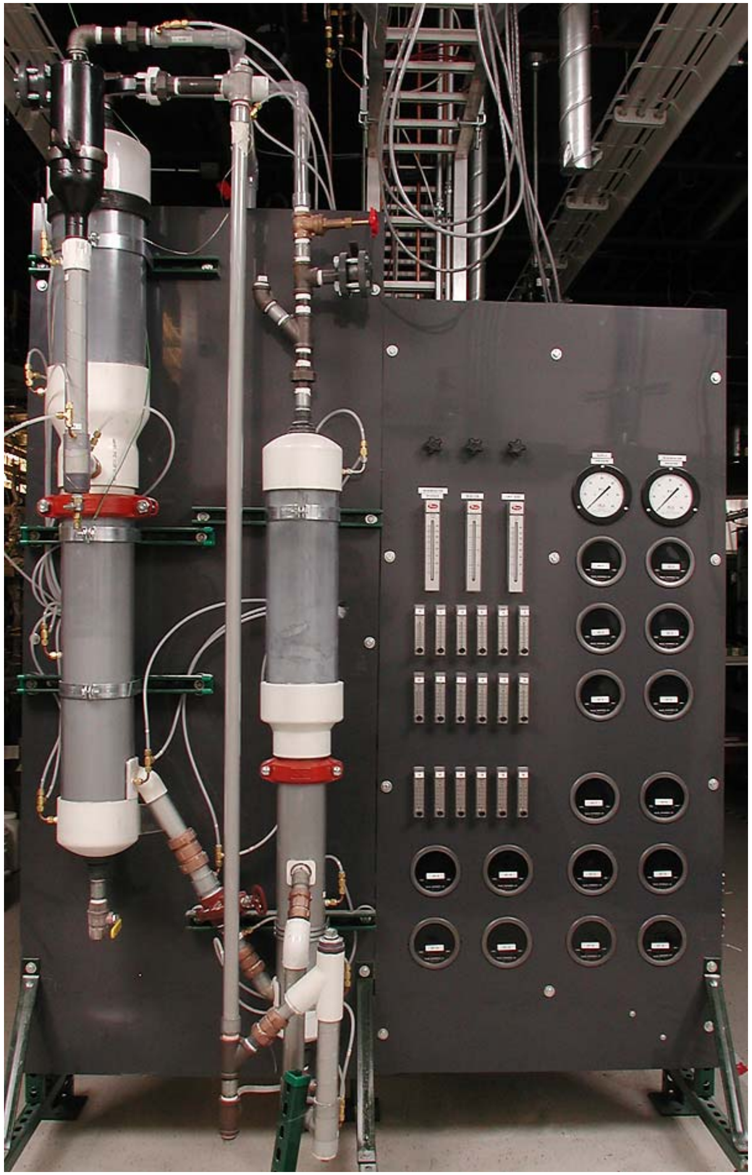
## Cold Flow Model




**Reactor Overflow Option with Loopseal**

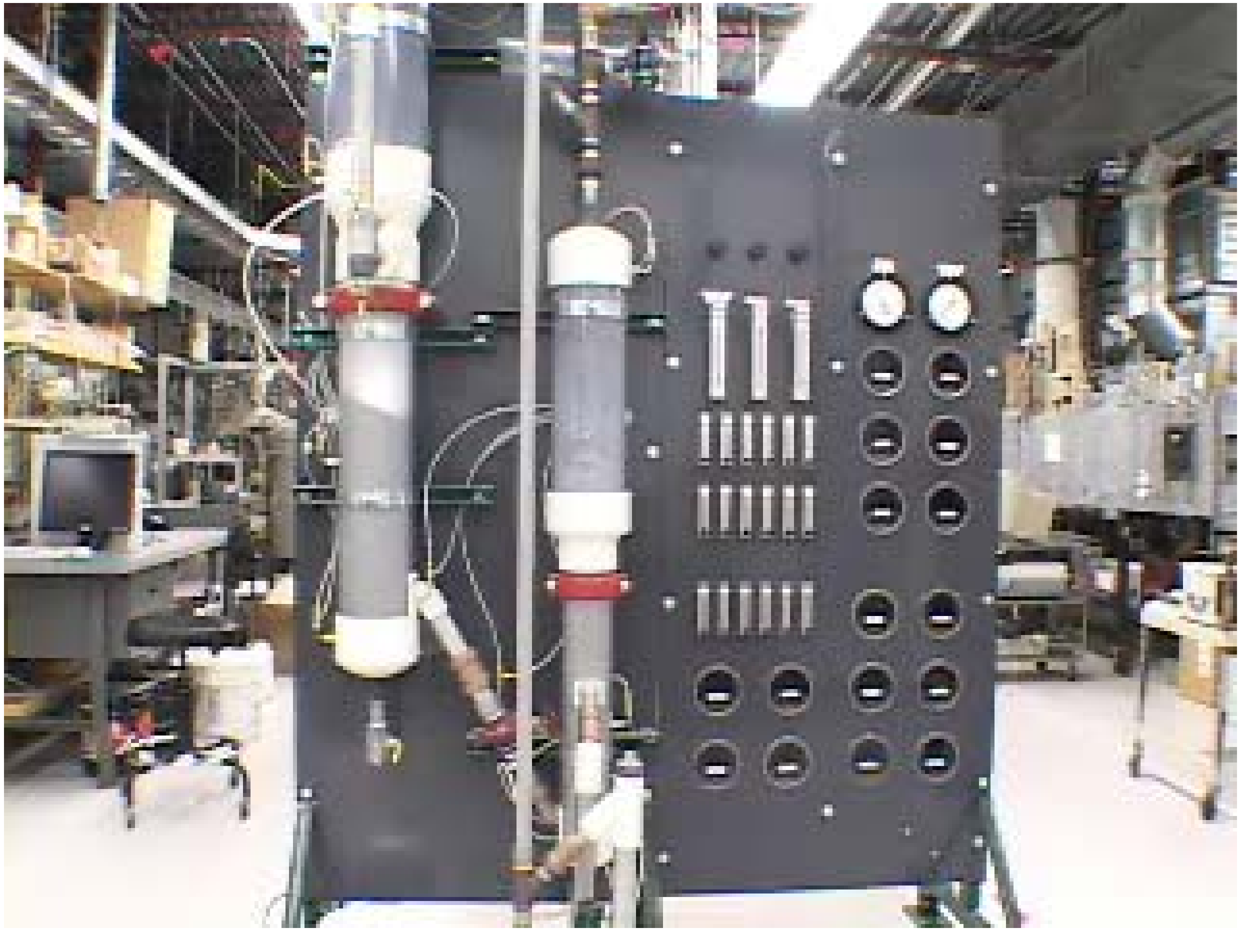
# History and Accomplishments





# History and Accomplishments

## Video of Cold Model



# Task 3
# Progress to Date

- Meetings have been held at Cratech and RTI to discuss fuel choices and integration of Cratech's gasifier with the therminator using a slip stream
- Gas and utility requirements have been determined for slip stream testing
  - syngas
  - compressed air
  - instruments air
  - nitrogen
  - cooling water
  - electricity

## Cratech Gasification System

- Operating Conditions
  - 1000 lb/hr ($7.5\times10^6$ BTU/hr; 500KWe)
  - 730ºC, 150 psia
- Fuels gasified
  - wood, rice hull, cotton gin trash, sugar cane bagasse
  - easy access to fuel supply
  - 3 to 40% moisture; 15% optimum
- Air-blown (can operate with $O_2$/steam)
- Steam Generator Available
- Hot candle filter (700-800ºC)
- Slip-stream testing capability
- Raw Gas Composition (Air Blown, Mole%)

# Cratech Fluidized-Bed Biomass Gasifier Typical Gas Composition (Raw, Wet)

| | Volume% |
|---|---|
| $H_2$ | 10.4 |
| $CH_4$ | 3.0 |
| $C_2H_4$ | 1.0 |
| $C_2H_6$ | 0.3 |
| CO | 17.0 |
| $CO_2$ | 15.3 |
| $H_2O$ | 12.0 |
| $N_2$ | Balance |

Contaminants (ppm)

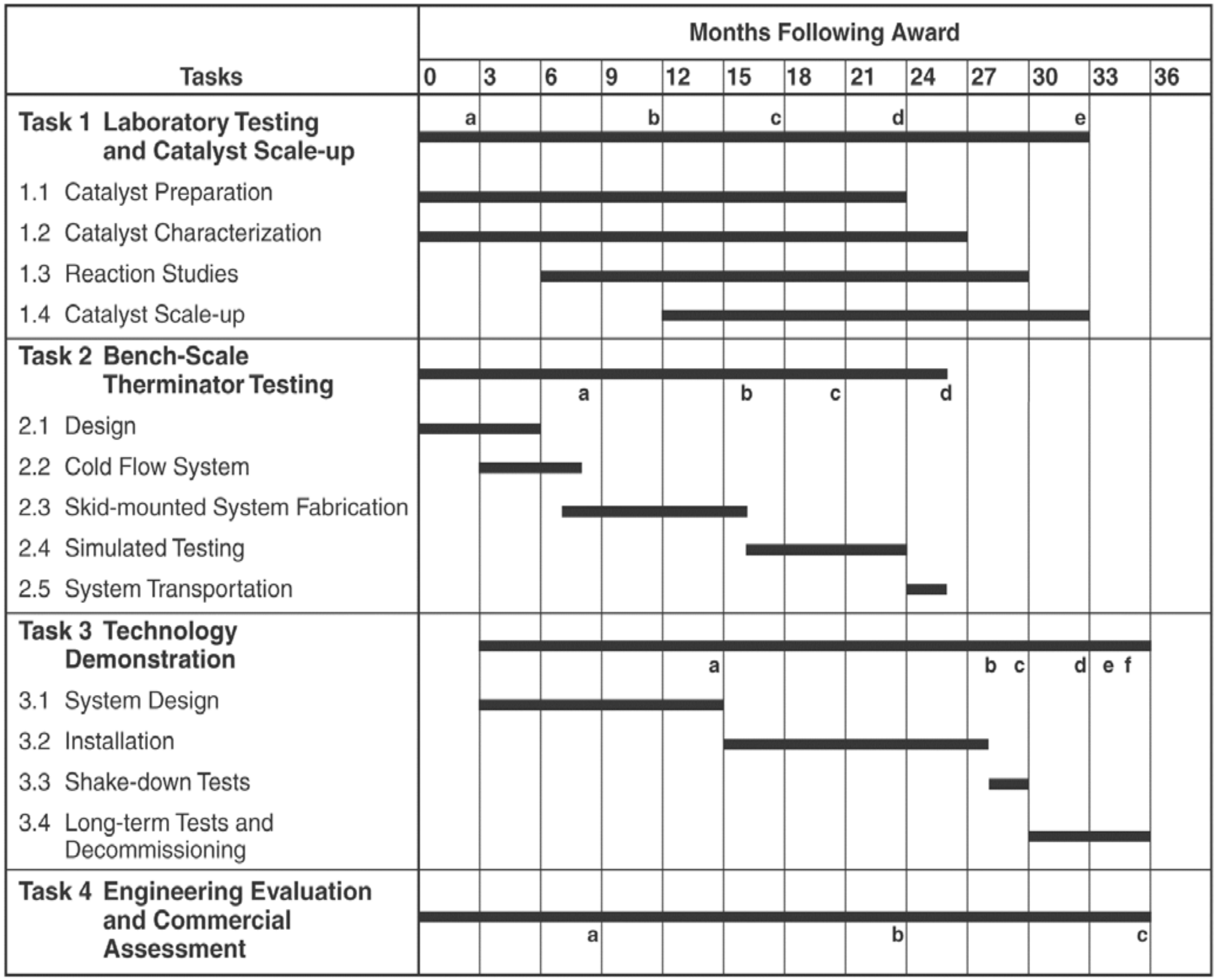
| | | | |
|---|---|---|---|
| $H_2S$ | 50 | $NH_3$ | 1,000 |
| Tar | 10,000 | Particles | 10,000 |

# Photo of Cratech Power Process Pilot Plant

## Task 4
## Engineering Evaluation/Commercialization Assessment

- Develop conceptual commercial process
  - electricity
    - engine
    - turbine
  - liquid Fuels
    - FT
    - alcohols
  - hydrogen
- Mass and Energy balances based on experimental data
- Marketing

# Project Schedule and Milestones



# Critical Issues and Show-stoppers



## Critical Issues

- cost of catalyst replacement due to attrition
- catalyst performance for reducing tar to < 0.1 $g/m^3$

## Show Stoppers

- no show stoppers at the present time

# Plans and Resources for Next Stage



- Project is on a research track and is at the stage of development research (Gate B)
- Key to success is the development and scale-up of low-cost attrition-resistant triple function catalyst system
- Development partners (Cratech, Sud-Chemie) have been included early in the program to provide guidance towards a commercial goal
- Successful development will move the project to commercial track Gate 4. Ongoing Task 4 will allow efficient technology transfer to involve commercial partner for demonstration at large scale.

# Summary

Project is presently on target with respect to achieving the required milestones

Project Funding:

| | |
|---|---|
| DOE: | $2 million |
| Participants: | $0.5 million |

FY05 Budget: $ 670 K